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CVT/PCS PHASE I INTEGRATED TESTING

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16. ABSTRACT <p>Five breadboard experiments representing three Sortie Lab experiment disciplines were installed in a Payload Carrier Simulator. The experimenters were asked to provide approximately 1½ pages engineering data, to provide an outline of the experiment protocol, and to simultaneously perform their experiments to their protocol for 8 hours per day, during the 4½ days of integrated testing. A description of the experiments and the Payload Carrier Simulator is provided. An assessment of the experiment interface with the Simulator and an assessment of the Simulator experiment support systems is presented. The results indicate that a hardware integrator for each experiment is essential; a crew chief, or mission specialist, for systems management and experimenter liaison is a vital function; a payload specialist is a practical concept for experiment integration and operation; an integration fixture for a complex experiment is required to efficiently integrate the experiment and carrier; simultaneous experiment utilization of simulator systems caused unexpected problems in meeting individual experiment requirements; experimenter traffic inside the dual-floor simulator did not hamper experiment operations; and the requirement for zero-g operation will provide a significant design challenge for some experiments.</p>					
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CVT/PCS PHASE I INTEGRATION TESTING

SUMMARY

Presented in this report are the results of the first Payload Carrier Simulator (PCS) integrated test. Included are assessments of the experiment interfaces and of the PCS subsystems. The critique identifies significant experiment/Sortie Lab interface problems and includes suggestions for improvements.

The test demonstrated the integration feasibility for a multi-discipline experiment payload for Sortie Lab missions, established the importance of the duties of a Crew Chief (Mission Specialist), and established the feasibility of a Payload Specialist. Information collected will support Sortie Lab requirement development, and help redefine existing PCS test methods.

INTRODUCTION

As the shuttle becomes a more predominant factor in NASA activity, the payloads for Shuttle missions present a significant integration and support challenge. Spacelab experiment accommodations and support must be flexible to accept different disciplines on successive flights and on the same flights at low cost and with rapid recycling of experiment complements on the ground. Low cost and rapid recycling are considered to be inconsistent requirements in reviewing Skylab and Lunar Landing Programs. It is clear that Shuttle Payload Carriers (i.e., Spacelab) require a new approach by NASA. A significant Project in defining this new approach is the Concept Verification Testing (CVT) Project.

CVT is a central NASA payload integration activity involving electrical, mechanical, and experiment breadboards, and a payload carrier simulator. The Payload Carrier Simulator (Fig. 1) consists of a Crew Quarters and General Purpose Laboratory and, provides the hardware for investigating experiment integration concepts for Sortie Lab. This early test involved only the General Purpose Laboratory (GPL) and five demonstration protocols and experiments: BioResearch Breadboard, Cloud Physics, Crystal Growth, Ionospheric Disturbances, and Acoustic Assessment. These can be summarized as follows:



Figure 1. Payload Carrier Simulator.

Bioresearch Breadboard — Principal Investigator, Dr. Tom Taketa, AMES RESEARCH CENTER. Biological studies involving rats, frogs, fruit flies, and lettuce plants.

Ionospheric Disturbance — Principal Investigator, Mr. George West, S&E-AERO-YS. Study ionospheric density, depth, and disturbance periods by transmitting at 4.0125, 4.759, and 5.735 MHZ, from three sites (90 miles from MSFC) and receiving the reflected signals in the PCS.

Crystal Growth — Principal Investigators, Mr. Rudy Ruff and Ms. Mary Helen Johnston, S&E-ASTN-MEV. Develop experiment equipment for crystal growth in space flight and secure ground based information concerning the effects of gravity on thermal convection and crystal growth process.

Cloud Physics — Principal Investigator, Mr. O. H. Vaughn, S&E-AERO-YE. Study fog formation and dissipation, using various chemicals as seeds, and photograph results.

Acoustic Assessment — Principal Investigator, Mr. Bob Erwin, S&E-ASTN-ADA. Measure increased noise levels resulting from experiment operations in the General Purpose Laboratory.

The experimenters were requested to provide the Test Team with the physical requirements for the experiment/PCS interface, to cooperate with the Test Team to develop detailed procedures for their experiment, and to checkout the experiment in the PCS. With these minimum constraints, the experimenters were then free to conduct their experiments as they deemed necessary, within safety limits. Observations by the Test Team were limited to the adequacy of the carrier to meet experiment and experimenter needs and the interaction of experiments.

In addition, a man/system assessment was conducted during the test. Any scientific results of the experiments will be addressed separately by the experimenters.

The purpose of this report is to describe the test, present the data collected, and consider the significant results of this first integrated test in the Payload Carrier Simulator.

APPROACH

Test Facility

The test facility consisted of the PCS, test control room, a data room, and utilities from Building 4619 (Fig. 2).

The Test Control Room was located adjacent to the PCS in room 158-A. This room served as the center for test operations and contained the necessary support equipment for the test team (including man/system integration personnel/experimenters.)

The data handling room (Room 142) was located in the west end of building 4619. Magnetic tape and strip chart recorders were connected to approximately 100 data channels that lead to the PCS. These recorders were utilized for experiment and PCS basic system data collection. Active instrumentation facilities available during this test are identified in Table 1. Data requirements included acoustic measurements and the metabolic function measurements of rats. The recorder and instrumentation for the rat metabolic function measurements were supplied by the Ames Research Center.

The PCS provided a test enclosure, representative of Sortie Lab's internal diameter, for experiments and experimenters during the period of testing. It is a cylindrical steel structure, 14.6-m (48-ft) long by 4.1-m (13.5-ft) internal diameter, (4.3-m (14-ft) external diameter with insulation). The PCS consists of a General Purpose Laboratory (GPL) Module, containing experiment support hardware and facilities, and a Crew Quarters (CQ) Module, containing living accommodations. The Crew Quarters Module was not utilized for this test, except that the refrigerator located in this area was used to store the Bioresearch Breadboard fruit flies during test operations.

The GPL module has two levels, lower GPL and upper GPL. A "zee" floor configuration (Fig. 3) provides two levels for personnel to work. This improves ground access (one-g operations) by maximizing the floor space and volume utilization for experiment hardware and crew workstations, and it will not impact zero-g operations. GPL floors are designed to withstand 4785 N/m^2 (100 lb/ft²).

The GPL upper deck level was primarily used for experiment operations (Ionospheric Disturbances, Crystal Growth, and Cloud Physics). The facilities included a sink and work surface area, volume for experiment hardware, and experimenter workstation areas (Fig. 4).

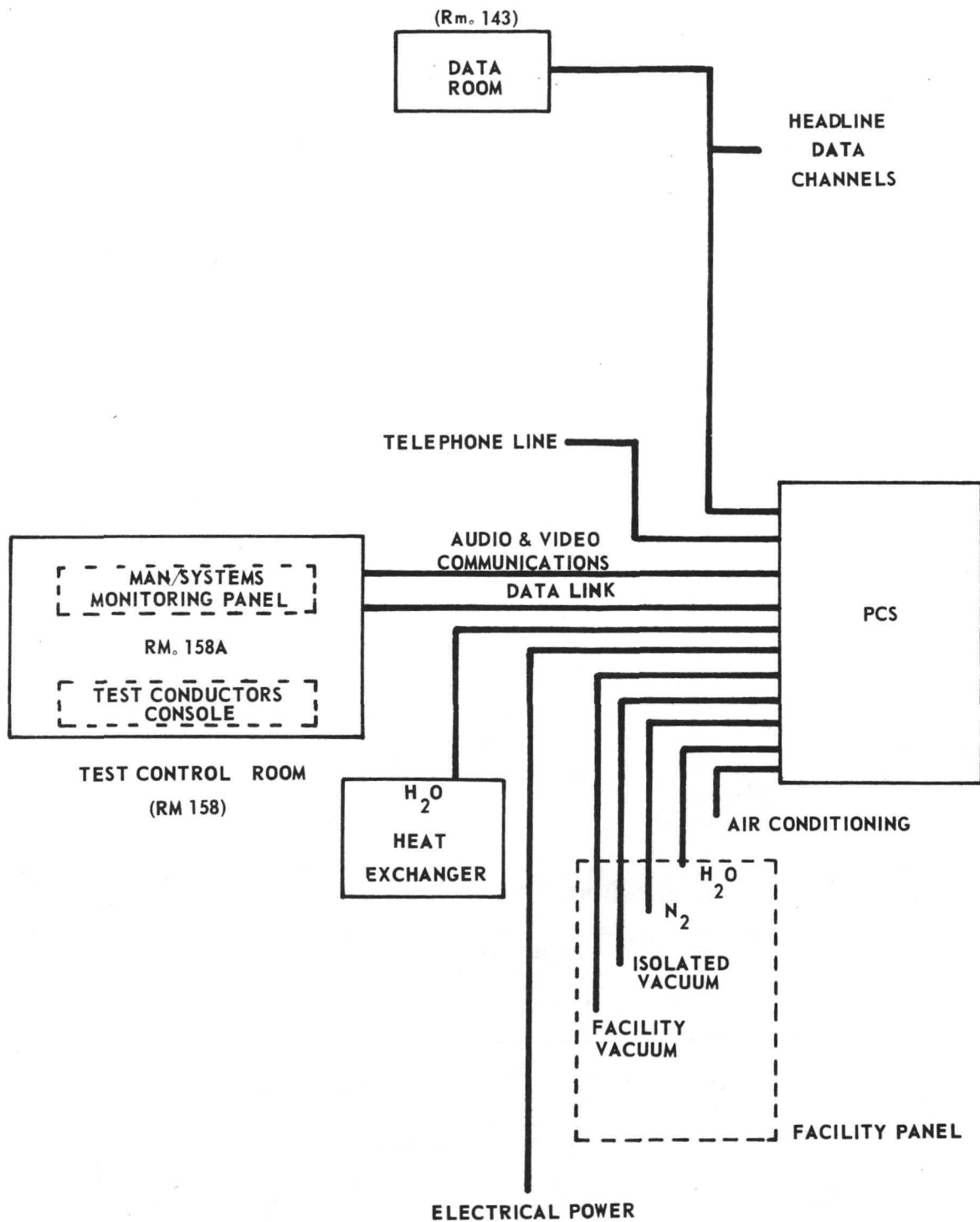


Figure 2. Test facility layout in Building 4619.

TABLE 1. TEST FACILITY INSTRUMENTATION

Measurement Identification	Description	Location	Readout and Range
B010-910	Acoustic Level	Upper GPL, West End	Magnetic Tape, Video Tape 10 to 80 DB
B011-911	Acoustic Level	Lower GPL, West End	Magnetic Tape, Video Tape, 10 to 80 DB
B013-910	Acoustic Level	Upper GPL, East End	Magnetic Tape, Video Tape 10 to 80 DB
B014-911	Acoustic Level	Lower GPL, East End	Magnetic Tape, Video Tape 10 to 80 DB
C011-911	Temp.	Lower GPL, South Side, Ambient, Behind "BEST"	Strip Chart 32-150°F.
Special	Temp.	Upper GPL, South Side Ambient, Behind "Ionospheric Disturbance" Receiving Station	Strip Chart 32-150°F.
H002-910	Percent R.H. GPL	Lower GPL	Analog Meter at Engineer's Console; Strip Chart 0-100%
M020	Total Power, GPL Three Phase	Power Panel	Strip Chart Recorder
	CO ₂ & O ₂ Heart Rate, Rat Temperature, Rat Deep Body Flow, Gas	Animal Cage, Environmentally Controlled, Lower GPL, East End	Digital Data System, Mag. Tape, Paper Tape Printout, ARC Furnished Sys., ARC to Evaluate Data

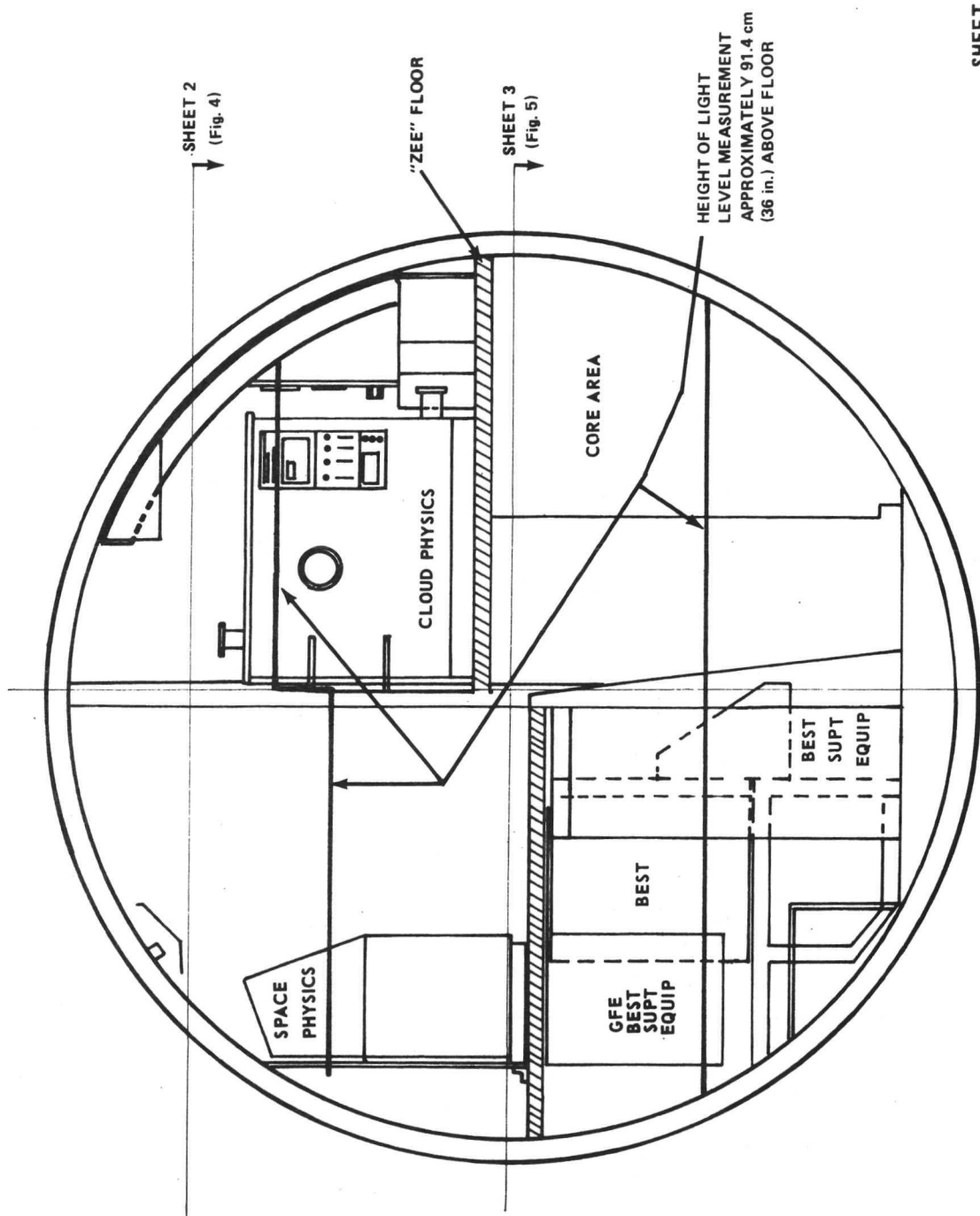


Figure 3. GPL experiment location.

Figure 4. Upper GPL, with light levels (Foot Candles).

The GPL lower deck level was primarily used for experiment support equipment, generally standard laboratory equipment. This equipment included an autoclave, a fume hood, a sink and work surface area, a refrigerator, a laboratory glass washer, and a distilled water center. It also housed the Bioresearch Breadboard during this test (Fig. 5).

Personnel access to the GPL is gained through a double 96.5 by 208.3-cm (38 by 82-in.) doorway at the outboard end of the GPL, or through a 96.5 by 198.1-cm (38 by 78-in.) opening into the crew quarters (CQ).

A ladder was located at each end of the GPL for access to the upper deck. This provided approximately a 101.6- by 81.3-cm (40 by 32-in.) opening for hardware transfer between decks.

The utilities provided to the PCS are depicted in Figure 2, and they are briefly described as follows:

Water: Hot water [64.9°C (150°F)] and cold water [23.1°C (74°F)] were supplied through 1.27-cm (1/2-in.) diameter tubing to two sinks in the GPL. A special system (ice bath heat exchanger) was utilized to provide 20°C (68°F) water at a rate of 9.4 liters/min. (2.5 gallons/min.) to the Bioresearch Breadboard.

Gaseous Nitrogen: Gaseous nitrogen (N_2) was supplied at a pressure of 6.895×10^6 dynes/cm² (100 psig) from 2.069×10^8 dynes/cm² (3000 psig) bottles located outside the GPL. The supply line was 0.635-cm (1/4-in.) diameter tubing and the flow rate was approximately 0.283 m³/min. (10 ft³/min.).

Air Conditioning: A 3-ton Trane air conditioning unit provided 3.53 m³/min. (125 ft³/min.) of air through a 30.48-cm (12-in.) duct to the upper GPL. The thermostat for this unit was located in the upper GPL. A 3.53 m³/min. (125 ft³/min.) recirculation blower on the upper GPL floor circulated the air by a duct system through the GPL and out an open door.

Electrical Power: Nineteen, 20 A, 115 Vac circuits, and six, 30 A, 208 Vac circuits were provided. A backup generator was connected to the power system in case of a major power failure. A 28 Vdc circuit provided power for valves used in Cloud Physics Study.

Communications: Audio communications consisted of Chief Redipower push-to-talk intercoms (model K-C-4906). Two units were located in the lower GPL, one unit in the upper GPL, one unit at the test conductors console, and one unit at the system console.

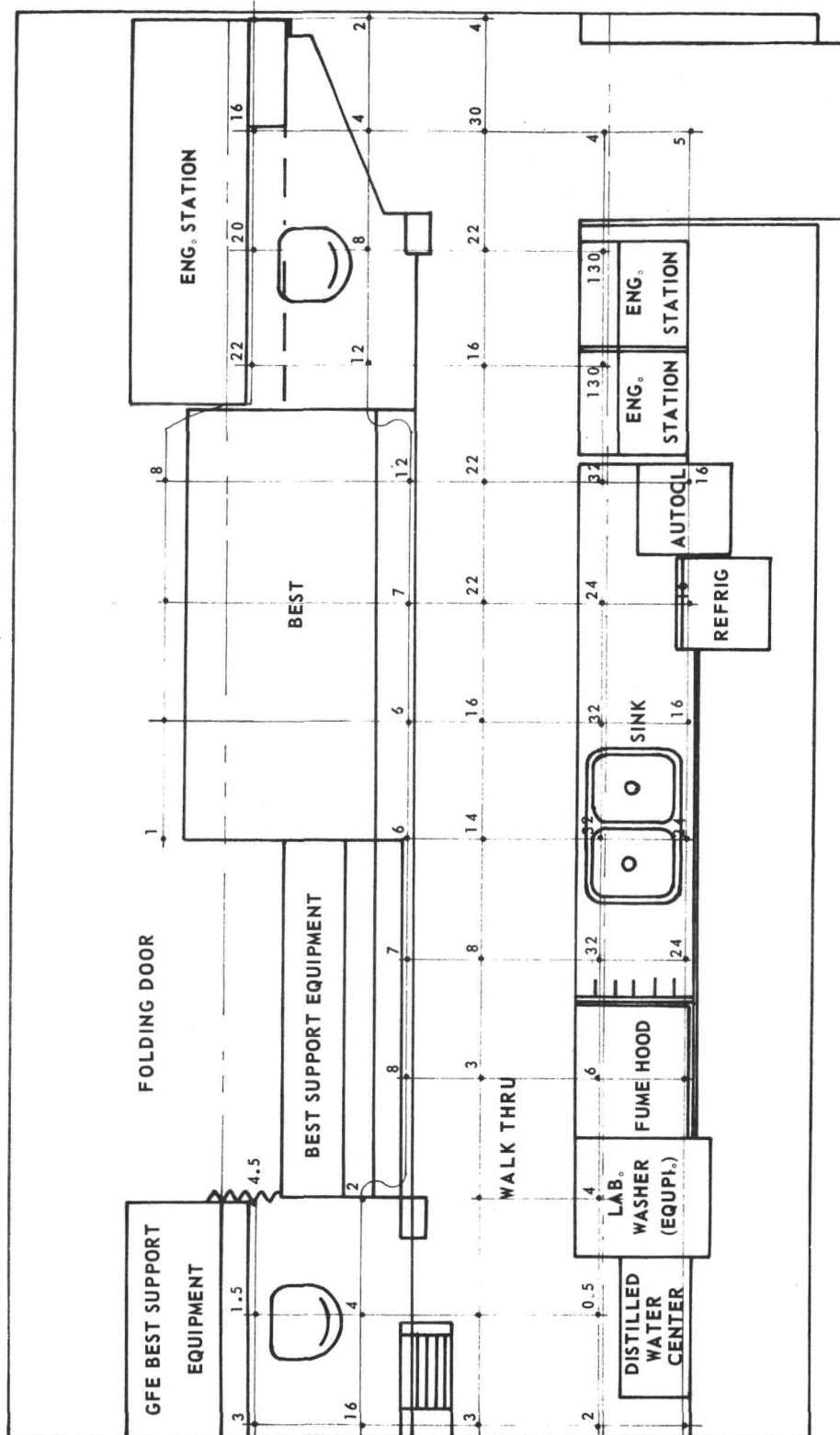


Figure 5. Lower GPL, with light levels (Foot Candles).

Video coverage was provided by five General Electric (GE) model 4TE3301, Black & White cameras and six monitors. All monitors were located in the test control room and video recording capability was available for any two cameras, simultaneously. Two cameras (one fixed and one pan/tilt) were located in the upper GPL, and three cameras (one fixed, one tripod mounted, and one pan/tilt) were located in the lower GPL.

Vacuum: Two vacuum sources were connected to the GPL. A facility vacuum was operated at approximately 3 Torr absolute and an isolated vacuum was operated at approximately 10^{-1} Torr. The facility vacuum was provided by the Building 4619 vacuum system, connected to the GPL by a 1.27-cm (1/2-in.) line. The isolated vacuum source was provided by a CENO HYVAC 45 vacuum pump connected to an approximately 0.17-m^3 (6-ft³) tank. The tank was connected to the GPL by a 1.27-cm (1/2-in) line.

Experiment Integration Procedure

After experiments were approved, hardware integrators were assigned to work with the experimenter in properly integrating the experiment into the GPL. The hardware integrator was responsible for updating experiment hardware status sheets, identifying and integrating new pieces of equipment, and identifying and solving interface problems. In addition, MSFC provided task analysis documentation for each experiment, and these were coordinated by the hardware integrator with the experimenter to ensure operational compatibility with other experiments and with the GPL.

Special Equipment

A special test fixture for the Bioresearch Breadboard was provided to AMES Research Center by MSFC, approximately 3 months prior to testing to aid in equipment integration. This test fixture was a metal structure, representative of the lower GPL floor. Ames subsequently outfitted this shell, installed the Bioresearch Breadboard, and conducted dry runs of each protocol (11 total) to be conducted with the Bioresearch Breadboard equipment.

Test Team

The operational test team organization shown in Figure 6 was composed of three elements: test conductor, a support organization, and simulator crew. The support organization was composed of engineer specialists in the

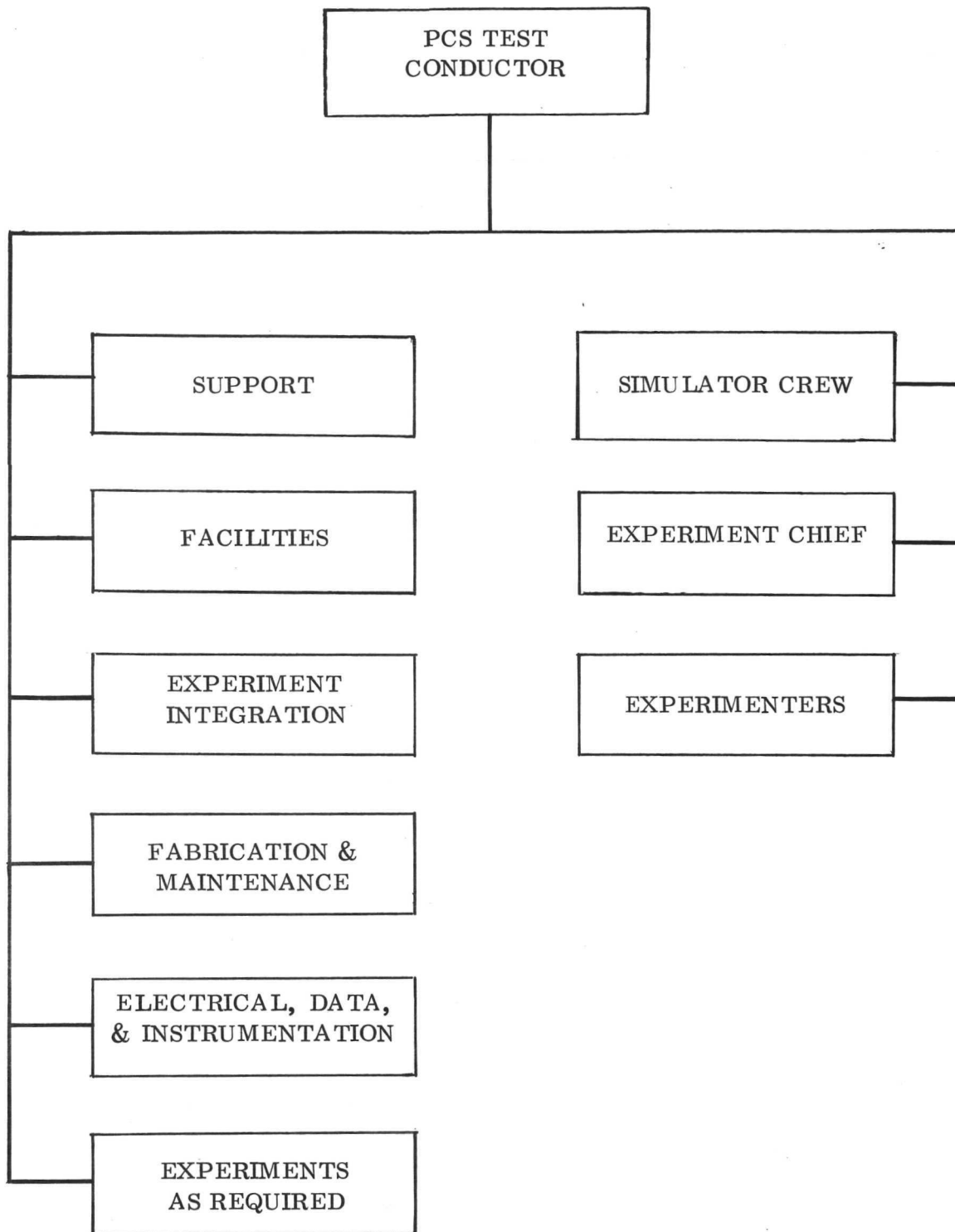


Figure 6. PCS operational test team.

areas of experiment integration, maintenance, instrumentation, and facilities. The experimenters were used, as required, to assist the crew in performing experiments. The crew consisted of a crew chief and the experimenter(s).

The Test Conductor was responsible for operation of the PCS for a period of 8-hours a day, or until relieved by an authorized test conductor. These responsibilities included the following:

- Direct the performance of all external functions in support of PCS.
- Maintain the required complement of support personnel at all times.
- Select and train a support crew (engineer and experimenters).
- Direct all communications with the crew.
- Declare any emergency conditions and implement emergency procedures.
- Maintain equipment logs.
- Ascertain location of "on-call" medical doctor.
- Preparation of all Test Reports.

The Support Engineer was responsible for monitoring all test parameters and maintaining the PCS operational status. The support engineer identified an on-call support staff and ascertained their location. The support engineer assisted the test conductor, as directed, in resolving operational problems.

The Crew Chief was an MSFC employee and was responsible for:

- Maintaining equipment logs, as required.
- Compiling and transmitting reports, as required.
- Monitoring PCS operating parameters, as required.
- Reporting anomalies to the Test Conductor for disposition. The Crew Chief was the lead crew member. The experimenters were only responsible for conducting their experiment.

Test Procedure

Two weeks prior to testing, a procedure was released. The test procedure provided ground rules for the testing, as outlined below:

- a. Experiments will be individually checked out prior to integrated testing.
- b. During the testing, a test team meeting will be held each morning at 7:30 a.m. and a debriefing will be held each afternoon at 3:30 p.m. On the last day of testing, the debriefing will start at 12:30 p.m.
- c. Constant audio and video communication will be maintained between the PCS and Test Control Room.

The experimenters were free to leave the PCS at any time as long as their experiment was left in a safe mode. They were also free to bring any support equipment or tools into the PCS as long as the Crew Chief was advised.

This procedure was followed as outlined above during the week of April 2-6, 1973.

DISCUSSION AND RESULTS

The following discussion covers the individual experiments, the GPL systems, and maintainability. This discussion addresses those areas of interest presented in the CVT/PCS Phase I Test Plan. Significant problems which occurred during the test are identified and discussed. A summary of results is provided at the end of each discussion.

Crystal Growth

Discussion

Czochralski crystal growth or crystal pulling is a technique by which a rotating seed crystal is dipped into a melt of the same material and then slowly withdrawn. The temperature of the melt is manually controlled, and a continuous temperature profile of the melt is recorded by a strip chart recorder. The rotating seed permits the crystal to maintain its symmetry.

A single crystal, formed at the interface of the seed and the liquid, is grown or "pulled" at the rate of upward withdrawal. After cooling, the crystal is characterized (etched and polished) before microscopic analysis.

Zero gravity provides a potential environment for ideal crystal growth conditions so that electrically active impurities may be minimized. Convection currents (known to cause growth rate fluctuations), boundary layer perturbations, and modification of intrinsic growth interface morphology can be eliminated. During the PCS mission, single crystals were pulled from melts of varying temperature gradients, enabling an assessment of the effects of convection upon the growth interface.

The crystal pulling experiment (Fig. 7) was located at the outboard end of the upper GPL (Fig. 4). This experiment was allotted a space 1.5-m (5-ft) long by 1.5-m (5-ft) wide. It also required a height of 1.7 meters (5 1/2 ft), necessitating a special location within the PCS due to the non-standard height. The experiment equipment was mounted in standard equipment racks and the crystal puller was mounted to an aluminum alloy plate installed in the top of the rack. The layout of the pulling unit and the standard relay rack was satisfactory for the experimenter's purpose. This location was clear of the aisle and free from traffic or physical interference problems with other experiments.

The experiment had no adverse effects on the PCS environment, nor did the PCS environment adversely affect the experiment. However, the furnace associated with the experiment gave off enough heat to be hot to the touch and should have been identified by a "High Temperature" label. Further experiments requiring higher furnace temperatures will require shielding.

During the early part of the mission, the experimenter suffered some annoyance with the PCS GN₂ supply interface. A fluctuating pressure resulted from simultaneous GN₂ use by the cloud physics experiment and this caused problems in reaching and maintaining a constant melting point temperature of the metal. The problem was solved by placing an 0.085 m³ (3 ft³) GN₂ surge tank in the line. A faulty regulator, which contributed to the problem, was also replaced.

Perhaps the major problem encountered was vibration of the molten metal. The slightest vibration, such as people walking in the upper GPL, was transmitted directly to the melt providing the potential for crystal aberrations. The experiment should be isolated from vibration by adequate shock mounting prior to future runs.



Figure 7. Crystal growth experiment.

A panel containing a small shelf was provided to the left of the crystal growth apparatus and next to the cloud physics experiment. As a result of the panel location, the electrical outlet was blocked and no longer easily accessible. The small shelf area did not provide a sufficient place for storing materials, working or writing. It is suggested a larger shelf be provided, capable of being used as a writing surface and mounted in a position that will not block electrical outlets.

The crystal puller was mounted so that the experimenter could spend the majority of his time seated with controls at arms reach. The low-height chair provided for the experiment required him to lean forward to observe the melt. A higher seat would be desirable.

After mounting the seed crystal into its holder and the metal slug into the furnace, the experimenter was required to adjust the temperature controls until the proper temperature level was reached in the melt. A period of 45 minutes to 1 hour was required to adjust the melt to the proper temperature. An automated temperature control system would allow better utilization of the experimenter's time. After the temperature stabilized, the experimenter could then shift his attention to positioning the crystal seed in the melt and begin the pulling activities. There were various adjustments of rotation and pulling speeds during this operation, depending on seed crystal and melt interface and the shape of the crystal being pulled.

During the mission seven crystals were pulled. In the latter part of the week the experimenter grew two a day, one before and one after the lunch break. The necessity for the experimenter to shut down the experiment apparatus to remove the pulled crystal caused a reduction in efficiency. After a shut down, the entire melting procedure had to be repeated before a new crystal could be pulled. A method for continuous pulling, after the proper temperature has been reached, would be desirable.

The pulled crystals were characterized in the latter part of the mission. Characterization involved etching in an acid bath and then polishing the crystals. This procedure necessitated the use of a fume hood located in the outboard end of the lower GPL, which involved transporting the delicate crystals up and down the stairwell. This was not only cumbersome, but also could be damaging to the delicate crystals. This problem could be solved by developing a carrying case to protect the crystal from damage while transporting it. A more ideal solution would be to locate a fume hood over the sink on each GPL floor, with all facilities available under the hood. The characterization procedure also involved observation of the crystal under a microscope. This

required the sharing of a microscope with the Bioresearch Breadboard, and at times there was a simultaneous requirement for its use. This indicates a need for more attention to mission timelines for the experiments.

Cleanup procedures were performed after each crystal was pulled. The used metal slug was removed and saved for possible cleaning and reuse. The glass tube, which provided a seal around the crystal, was wiped clean with solvent and a new slug was placed in the crucible. This required the disassembling of the pulling gear shafts and a corresponding reassembly before the next run.

There appeared to be no problems of access to the experiment for either set-up or maintenance of the equipment. The only maintenance problem was a vibration of the recorder pens, which developed because of the excess electrical noise. This problem had previously occurred in laboratory tests, but had been sufficiently reduced to the point that data acquisition was good.

The experimenter brought a general tool kit onboard to perform set-up and maintenance requirements for his equipment. This kit consisted of the following:

Allen wrenches	Assortment of bolts and nuts
Adjustable wrench	Tweezers
Tongs	Recorder pen refills
Screwdrivers	Pen cleaner
Jewelers saw	Ink refill
Wire cutters	

Since very little storage space was needed, the tools were generally stored in the bottom compartment of the equipment rack. The remaining few items were placed on the shelf adjacent to the experiment.

The experiment required no GPL instrumentation, but it did require a controlled GN_2 pressure at the experiment. This was provided by a regulator and gage. Some gas leakage was suspected around the rotating rod. It is suggested that in future testing, a meter be placed on both sides of the equipment to assess the amount of leakage. Also, a more effective seal should be developed for future runs.

Timelines were relatively accurate. More time was needed than previously predicted for placing the metal slug in the crucible and aligning the seed crystal. The time required for actually pulling the crystal varied between 22 and 40 minutes. In general this experiment functioned as desired according to available laboratory procedures and task analysis without any major problems.

Summary of Results

- Experiment should be isolated from vibration by shock mounting.
- Crystals are delicate and their transportation should be minimized. This suggests that a fume hood also should be placed on the upper floor.
- Considerable experimenter time (45 min-1 hour) is consumed for each crystal, waiting for the metal to melt. A manual interface exists with the temperature controller that could be automated.
- Simultaneous GN₂ use by crystal growth and cloud physics produced GN₂ pressure instability.

Cloud Physics

Discussion

The Atmospheric Cloud Physics experimental objectives during the initial Phase I test were: (1) operational checkout of experiment equipment and procedures, (2) human factors assessment of the procedures and the experiment/PCS interface.

The experiment was constructed inside the GPL, and was not tested until a preliminary checkout during the week prior to the mission. The discovery of leaks in the main cloud chamber during this checkout and the inability to repair these leaks with the chamber installed, necessitated the removal of the main chamber and subsequent loss of the primary demonstration objectives and major interface interest. This indicates the need for complete operational checkout before an experiment is brought onboard.

The experiment (Fig. 8) was located in the upper GPL, as shown in Figure 4. The area allowed for this experiment was 1.8 m (6 ft) in length and 1.2 m (4 ft) in depth. After the removal of the main chamber, this



Figure 8. Cloud physics experiment.

space proved excessive and the experiment, as run, could have been located in an area 1.2 m (4 ft) by 0.9 m (3 ft). The experiment location presented no noticeable traffic or physical interference problems with the other experiments. A work table and writing surface which was provided for the experiment proved to be inconvenient to the experimenter, because the primary work area shifted away from the work table when the main chamber was removed.

The experiment had no adverse effects on the PCS environment. All of the valves and plumbing were built-in hardware and were contained behind display panels. They all functioned properly in the system used. There were no problems encountered in supplying the levels of vacuum and GN_2 pressure requested by the experimenter; however, the required use of GN_2 by Cloud Physics did impact the crystal growth experiment (as previously discussed). The use of the vacuum supply reduced the capability of the isolated vacuum system to support the Bioresearch Breadboard. The latter problem was eliminated by scheduling the use of the isolated vacuum system.

Because of the failure of the main chamber, the particle counting system was the only equipment that was operational during the actual mission. The experiment operation consisted of a valve actuation sequence and the observation of the resulting particles which were illuminated by a low-power laser beam shining through the thermal diffusion chamber. Ice was used as a coolant in the thermal diffusion chamber to establish a temperature gradient across the chamber. Crushed ice (100 ml) was brought onboard the PCS twice each day during the time the experiment was run.

The experimenter was never able to obtain photographs of the particles with his polaroid camera system. A light-proof box with a different type of source beam will be needed before photographs can be taken. Light shielding attempts, using black cloth and black paper, were unsuccessful during the mission.

A significant experiment maintenance problem was encountered during the mission. During operation, there was a rupture in the conditioning chamber wall caused by over pressurization with GN_2 . The experimenter had no capability to repair the chamber, onboard, and the experiment was terminated until another chamber could be brought onboard and installed. There were no envelope or access problems involved in the maintenance. The experimenter did not have the tools to perform the maintenance, but was able to obtain a hand drill, a slot screw driver, and a pair of pliers from the crew chief's tool box to complete the maintenance. The problem caused an experiment interruption of approximately two hours, but the quick fix allowed the experimenter to still meet his revised objectives. The rupture could have been prevented

with a relief valve in the pressurization system of the chamber, and it is recommended that one be included in future designs. The foregoing problems resulted from a human error in the valve operation procedures. A rapid recovery capability for problems, such as this, points up the need for an on-board tool kit capable of handling contingencies and maintenance.

There were no GPL instrumentation readings or data recordings required by the Cloud Physics experiment. All pertinent data were monitored from gages available on experiment panels or from a strip chart recorder at the workstation.

As previously mentioned, the failure of the main chamber eliminated major interface interests, including waste trapping and cleanup procedures. This also considerably reduced the experiment time lines and task analysis. However, the task analysis proved quite valuable in establishing detailed operating procedures for this experiment.

Summary of Results

- Main chamber exhibited massive leaks during GPL checkout and was removed during integrated tests. Proper equipment checkout in the laboratory would have identified the leaks in time for a fix prior to testing.
- A different system is needed for proper photography of cloud particles.
- A significant maintenance problem further established the need for an on-board tool kit and aided in its definition.

Ionospheric Disturbances

Discussion

The Ionospheric Disturbance Experiment was designed to study the characteristics and changing nature of ionospheric conditions in the upper atmosphere. The three-dimensional motions of upper layer disturbances were measured by the high frequency Doppler technique, with geographically dispersed transmitters operating at several probing frequencies.

The three transmitters sites were located at Ft. McClellan, Muscle Shoals Dam, and Nickajack Dam. All were within 144.8-km (90-mile) radius of the PCS and transmitted on frequencies of 4.0125, 4.759, and 5.735 MHz.

The transmitted frequency was controlled by a highly stable crystal oscillator. Following reflection of the transmitted signals from various layers of the ionosphere, the signals were received on three separate receivers in the PCS. The transmissions were continuously recorded on magnetic tape, which was operated at a speed of 2.54 cm/min (1 in./min).

The Ionospheric Disturbance Experiment (Fig. 9) was located in the upper GPL as shown in Figure 4. All of the equipment was mounted in four standard slope front electronic racks, and occupied an area 3-m (10-ft) long by 0.66-m (26-in.) wide. This experiment presented no physical interference problems with any other experiments. While performing checks on his equipment, the experimenter created a partial blockage of the aisle and one television camera which was being used to collect man-systems data. Because of the automated nature of the experiment, the equipment checks were infrequent and the problem of aisleway blockage was not a significant one. The television camera should be more advantageously located for future runs to prevent the loss of man/system data.

The experiment became operational before integrated testing began (April 2-6). During integrated testing, the experimenter periodically checked his equipment to determine if the transmitting sources were operating properly and being received correctly. This check was usually conducted three times a day, for about thirty minutes at a time, and usually consisted of listening for the call signals that were broadcast from each transmitting site. The high frequency transmitted call signals were a minor disturbance to the crystal growth experimenter. This disturbance could be eliminated by the use of headphones for monitoring call signals in the future. During the experiment check, any fine tuning, controls adjustments or necessary maintenance were also performed. There was a direct line telephone contact provided between the GPL and the transmitter site; however, during the test week, there was no contact made with any sites. At least two transmitters were inoperational at one site, but flooding conditions made this site inaccessible and no fix was attempted during the test week.

There was no onboard analysis attempted during the test week; however, there was sufficient experimenter time to have done so, if desired.

All receivers were operated continuously from activation, without any malfunctions or maintenance. During the test week, two tape recorders were operated simultaneously, one serving as a back up for the other, in case of malfunction. The use of two recorders also enables one to be played back to check previous recordings, without the loss of any incoming data.



Figure 9. Ionospheric Disturbance Experiment.

During the test week, only a portion of one spool of tape was used (one spool of tape records approximately 17 days data). Approximately one roll of chart paper was used during the week for spot checks of the data. A storage space of 0.6 m (2 ft) by 0.6 m by 0.6 m was adequate for all supplies needed by the experimenter. Spares included extra paper, spools, and tape. A supply kit is now being prepared for use in future runs.

This experiment had no interface with the PCS data collection facilities, with all data being collected by the onboard experimenter. The only facility requirement was 110 Vac electrical power.

The experiment was highly automated and required very little maintenance. The only experimenter interface necessary was to check all transmitting stations for operation, to daily review previous data, and to change tape when necessary. With a minimum of training, the Crew Chief would be able to perform these duties, eliminating the need for an onboard PI for this experiment. Space could be optimized by using solid state devices to replace the larger, heavier, tube type receivers used in this test. Miniaturization would increase experiment cost two or three fold.

The basic zero-g manned interface with this equipment should require no alteration. Most of the operation is automatic and the man interface is primarily that of monitoring. This experiment could not be performed from a seated position, since the operations required movement between the various racks of equipment. The experimenter was observed squatting, bending, and reaching to make observations and adjustments. A more optimum means of arranging the equipment needs to be investigated.

Overall, the experiment functioned quite smoothly, according to the established procedures, except for some last minute equipment installation on the first day of the mission. This created some congestion and blockage of the camera in the upper GPL.

Summary of Results

- Experiment is automated and has limited manned interface.
- Zero-g interface requires little alteration — miniaturization optimizes volume requirement but increases cost 2 or 3 fold.
- Experiment encountered few maintenance problems.

BioResearch Laboratory Breadboard

Discussion

The objectives for the BioResearch Laboratory Breadboard were to evaluate two major pieces of hardware, the Biological Experiment Support and Transfer (BEST) Unit and the BioResearch Support (BRS) Unit, and to evaluate integration concepts and to identify operational interface problems for an evolving Life Sciences Program. The BEST and BRS modules were designed such that together they should be able to provide necessary support of bioresearch.

Diverse representative protocols were subsequently chosen to adequately determine the capability of this equipment. The seven protocols using vertebrates involved metabolic measurements, blood sampling and analysis; rat surgery; fatty acid determination; tissue biopsy; and amphibian maintenance, mating, fertilization, egg collection, and embryo cultivation. One protocol involved plant maintenance, morphology, and tissue preservation for biochemical analysis. Another protocol involved *Drosophila* mating, egg production, activity and preservation. The remaining two protocols involved micro-organism contamination control and tissue culture growth. This brief summary suggests the scope and magnitude of the protocols.

Coupled with the protocols complexity was the fact that one experimenter functioned as a payload specialist, representing several principle investigators (PI's). This situation could have precipitated numerous problems, except for the thorough preparation of the payload specialist prior to the mission. Pre-mission planning included familiarization and checkout of the procedures, using a test fixture previously described with similar equipment layout, prior to shipment of equipment and organisms to the GPL facilities.

The BEST and BRS modules were installed in the GPL three weeks prior to testing and were made operational during the week prior to the integrated test.

Upon arrival of the organisms, it was obvious that incomplete preparation had been made for organism maintenance, as defined by the P.I. Problems included the lack of cooling water, provisions for 20°C storage of the *Drosophila*, and adequate nutritional requirements for the organisms. These problems were quickly altered to an acceptable level, however, they brought out significant implications for Sortie Lab Payload pre-launch facility planning. All anticipated experiment disciplines must be carefully analyzed to determine pre- and post-launch specimen and equipment, ground operations equipment, and facility requirements.

The Bioresearch Breadboard was located (Fig. 10) in the lower GPL (Fig. 5) which also housed the engineer's station and the Common Operating Research Equipment (CORE). The BRS occupied an area approximately 2.1-m (7-ft) long by 0.6-m (2-ft) deep, and the BEST occupied an area of 3.1-m (6.8-ft) long by 0.79-m (2.6-ft) deep. Another space of approximately 1.2-m (4-ft) long by 0.6-m (2-ft) deep was utilized to isolate the Rat Heart Rate Respiratory Metabolism portion of this protocol. This provided an adequate operational envelope that still allowed access to the BEST Unit for maintenance. There was a traffic problem noticed when more than two people were in the lower GPL. Rearrangement of existing equipment would do little to alleviate this problem, without eliminating maintenance accessibility to the BEST Unit. It should be noted that this problem would be reduced in a zero-g environment. The payload specialist recommended that the lower deck be limited to two people during the operation of this protocol.

The protocols had no adverse effects on the GPL environment; however, there were some minor GPL environment problems encountered in support of the protocols. Additional lighting was necessary above the BRS and the glove boxes, and additional fans were installed to circulate air behind the equipment racks. Improper circulation of GPL cooled air to the lower deck caused uncomfortably high temperatures for the experimenters. It should be noted that neither the autoclave nor lab washer was needed during this time. Their use would have greatly added to the heat load. The problem resulted from the location of the recirculation system on the upper level, which was then unable to return enough cool air to the lower level to sufficiently cool it. The problem was solved by closing the upper deck recirculation vents and forcing more air to the lower deck. There were also problems associated with access to the storage areas. The drop doors on the storage cabinets above the sink would not remain open, and the handles to other cabinets were too small for ease in opening them. The experimenter had difficulty in reaching those cabinets above the working area. The storage area under the microscope working shelf was hard to reach when the shelf was out for use. These areas will be investigated for design improvements.

The 10^{-1} torr capability of the isolated vacuum system could not be approached while the Cloud Physics experiment and the Bioresearch Breadboard were simultaneously using the vacuum system. It proved easy to schedule around this problem since cloud physics used the vacuum only intermittently and Bioresearch Breadboard required this low level only for those protocols making use of the Lypholizer.

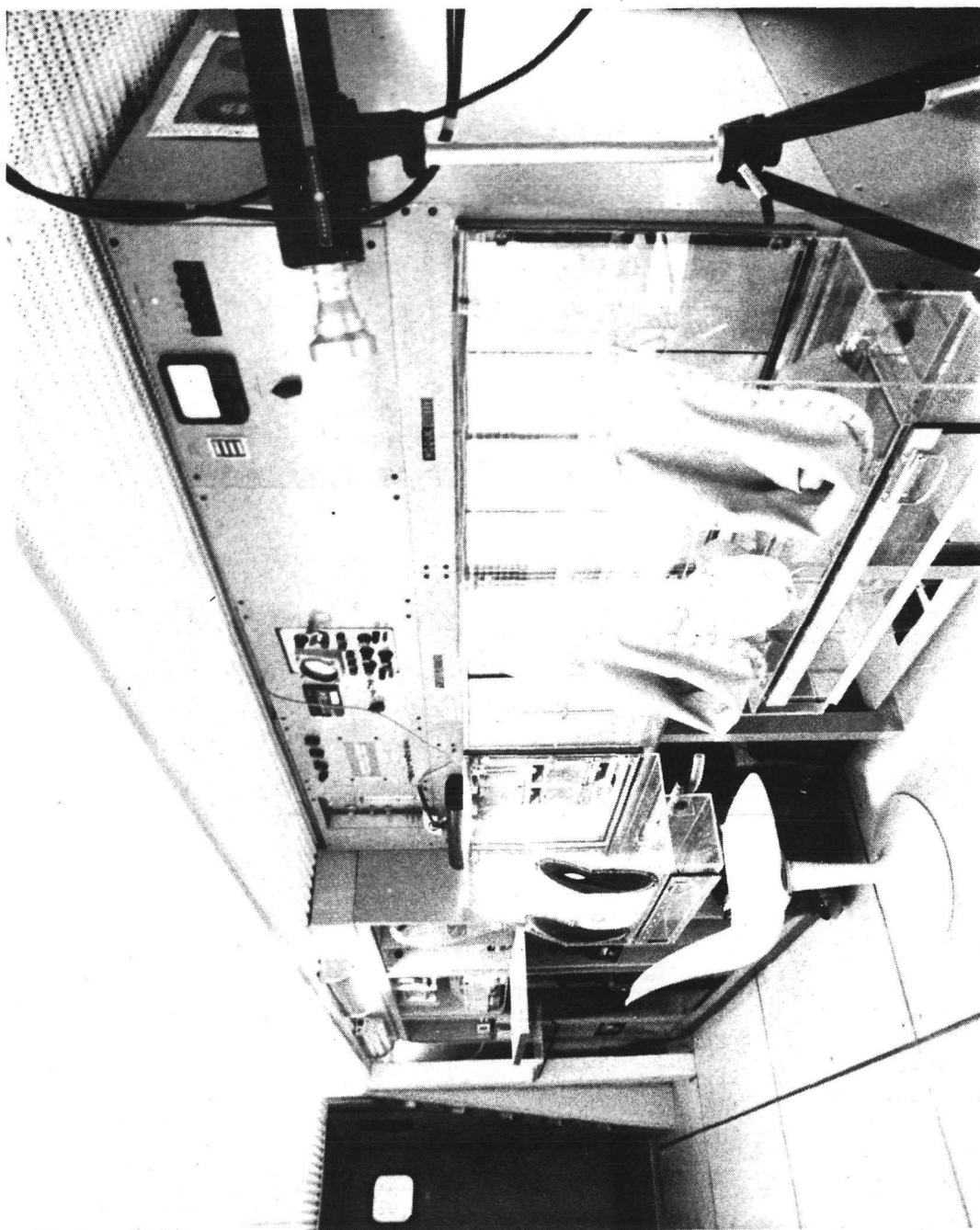


Figure 10. Bioresearch laboratory breadboard.

The BEST filtering and conditioning system was adequate to handle the odor of the plants, animals and chemicals inside the open door GPL environment. None of the above odors were noticed in the GPL environment for this test run, however, this should be further examined in a longer duration mission.

As a result of this test run, the experimenter felt that the glove box requirements could be relaxed. A glove box with portholes was preferred over one with sterile gloves since the primary function was to physically contain the organisms in a limited space. The glove box portholes didn't allow a full range of movement; they should be larger or possibly elliptical instead of circular. There was also some difficulty in positioning the chair close enough to the glove box for a comfortable reach inside. A higher chair or swivel stool should be considered as a possible improvement.

All plant and animal handling and feeding during the test was performed internal to the BEST holding facilities. The lettuce plants seed plugs were inserted into a rotating cylinder, with water, containing nutrients, supplied to the cylinder. The water was added to the desired level by depressing a plunger. The nutrient tablets were added to the water reservoir prior to filling the cylinder. After the initial experimenter interface, the plants were placed in their proper environment and no other interface except watering was required prior to harvesting. With the exception of the rotating cylinder, this system functioned as it would in a zero-g environment.

Rat feeding was an automated procedure. The food dispensers in the BEST were initially filled with food pellets which were available to the rats, as desired. The dispenser did not need to be refilled during the test week. Water was continuously supplied to the cages.

There was a more significant GPL interface with the frog feeding procedures during the test. The food was liver, which was removed from a freezer, thawed, cut into pieces, and divided among the frogs.

Most animal handling was done under glove box operations. There were no problems with holding the rats to apply anesthetic or other injections. Any time the rats were removed from the glove box they were in a holder. There was a great deal more difficulty in handling the frogs. They continually slipped from the experimenters hand while he attempted injections. Gloves made from a "terrycloth" material might be helpful for holding frogs. When transferred out of the glove box for weighing, the frogs were enclosed in plastic bags. All cleanup and egg collection was performed within the glove

box, requiring the soiled water to be placed in one container and removed from the box for disposal. All these were performed as one-g operations and indicated a significant tool and fluid restraint problem in zero-g conditions. Some restraining measure, such as Velcro, should be used for attaching tools and equipment to locations near working surfaces.

All cage cleaning and waste collection were glove box operations. The waste was usually placed in plastic bags, removed from the box and placed in the trash management system. After surgical procedures, requiring animal sacrifice, the cadavers were placed in plastic bags and removed to the trash management system. Cleanup and waste collection were usually performed at the close of each protocol or at the close of a glove box operation. Sterilization and tool cleanup procedures were not addressed in this test.

There was a large storage space requirement for these protocols. The entire lower GPL storage was made available and proved adequate. The materials were generally stored by kits, with all items needed to perform a particular protocol being together in storage. General laboratory items such as test tubes, pipettes, tissues, and glassware were stored in a common location.

The only maintenance required during the test week was to repair a water leak in the BEST and to attach and remove the glove boxes. The only tools needed for this were a screwdriver and an adjustable wrench. It is doubtful that the payload specialist could have maintained the BEST if the need had arisen. The complexity of the BEST unit's system necessitates a trained technician for anything other than minor maintenance problems. With prior instruction about the unit's system, it is possible that a "talk through" maintenance procedure could be utilized.

There was an interface between the GPL Instrumentation and data collection system and the protocols. The majority of the desired information was provided at engineering panels onboard the GPL. The heart rate/respiratory metabolism protocol did transmit data outside the GPL to an AMES provided tape recording system in the control room. No problems were observed with any of the data collection facilities.

The operations for these protocols closely followed the test procedure and established task analysis. The only deviations from the Payload Specialist outline was in the plant morphology and tissue preservation protocols. These deviations were necessary since both light and water had to be increased for

plant maintenance. The timelines were relatively accurate, however, about four hours were gained during the five-day mission. The task analysis would have been more useful if more detail had been transmitted to aid those persons less knowledgeable in Life Sciences.

Camera coverage was considered inadequate. Better closeup capability was necessary, as was better camera location. The Crew Chief provided improved camera coverage on request.

More work bench space was needed for these protocols and it should be a zero-g design. Zero-g concepts for waste management, foot restraints, mobility aids, fluid handling, and scales for weighing should be addressed in future planning. Procedures, lists, and other written materials used by the experimenter in the future, should be fixed to a convenient surface near the work space.

Overall, the GPL facilities were adequate for the protocols performed. The wide variety of protocols carried out testify to the flexible nature of the GPL facilities.

Summary of Results

- There is a significant need for pre-launch ground facility planning for Life Science protocols.
- Two people proved to be the optimum concentration for the lower deck.
- The Bioresearch Breadboard experimenter acted as a payload specialist by performing 13 principal investigator's protocols successfully.
- There was a significant zero-g equipment handling and restraint problem in performing the protocols.
- Animal metabolic studies require an isolated area.
- The use of an integration test fixture proved a valuable integration tool.
- The Bioresearch Breadboard requirement of 10^{-2} Torr was never obtained from the PCS vacuum system. 10^{-1} Torr was available and adequate when the Cloud Physics Experiment was not operating.

Acoustic Assessment

Discussion

The Acoustic Experiment microphones and sound level meters were mounted at four locations, two in the lower GPL and two in the upper GPL. These microphones were wall mounted and non-intrusive to the other experimenters on board. The microphones were operational throughout the test and were hardwired to the data recording room. This experiment did impact the test on the first day, because of the large number of people onboard to aid in the setup and calibration.

The experiment required very little experimenter onboard operations. There were four different acoustic measurements runs during the test week. The first two runs measured acoustic levels with all experiments operational. This required entering the GPL and manually setting the range of the sound level meters. In future runs the recording system should be automated to prevent unnecessary traffic in the GPL. During the third run, the experimenter walked through the GPL with a hand held sound level meter while all experiments were operational. This provided an immediate estimate of the spectra for a quick-look assessment. The fourth run was a post-test determination with all experiments shut down. The data from this run confirmed that the previous recorded levels were by the experiments and not from outside of the GPL. The noise levels were within the original CVT guidelines for laboratory areas during routine activities. The average of the 600-1200, 1200-2400, and 2400-4800 Hertz Octave Band levels was approximately 50 db. It was also determined that external noise levels were sufficiently attenuated and did not seem to affect the GPL internal acoustic environment.

The experiment produced no adverse effects on the GPL environment nor was it adversely affected by the GPL. It required no storage volume or waste control. All sound level meters worked properly and no maintenance was required during the test week, with the exception of the first day.

Available test procedures were followed closely, and the experiment operated as it was timelined.

Summary of Results

- Required little experimenter interface.
- PCS noise levels were within established laboratory guidelines and normally were below 50 dB.

GPL Systems Assessment

This discussion concentrates on the GPL, its facilities, and subsystems. It specifies those problems that developed during this test run and provides the basis for some of the conclusions drawn from the text.

This initial test proved a good driver of GPL systems and indicated a surprisingly good first-cut at systems requirements. The present configuration offered adequate storage space and experiment volume to all experiments on board. Because of the full work schedule of the Bioresearch Breadboard experimenter, which required extensive use of the aisle, more than three people created a significant traffic problem in the lower GPL. There was no apparent interference among the three experimenters in the upper GPL, indicating good integration and isolation of experiments.

Two significant environmental problems resulted from the test. The lower GPL temperature remained at a high nominal level of 23.3°C (74°F) as compared to a nominal level of 20.9°C (69.5°F) for the upper GPL. This points out a need for a design change in the recirculation system of the GPL air conditioning system. The other problem was that of inadequate lighting above equipment racks in the lower GPL. As a result of this problem, two additional fluorescent lights were installed. In general, the lighting furnished by the 30 and 40 watt fluorescent fixtures was adequate. Upper and lower GPL point light levels are indicated in Figures 4, 5, 6.

GPL facilities were in general quite adequate. Total power levels were generally in the range of 3600-4200 watts with a peak load of 5000 watts. The available circuits were capable of handling all voltage and current demands. GPL plumbing was generally undersized and resulted in upper sink drain overflows. Vacuum line undersizing also contributed to reduced vacuum capacity which occurred during simultaneous use by experimenters. The N₂ system provided sufficient pressure levels to all experiments, however, there were pressure fluctuations at the crystal pulling experiment that were eventually solved by installation of a surge tank in the line and a new regulator in the experiment. The only item of the standard laboratory equipment used was the fume hood and it was shared by two experimenters. It has been suggested that it be relocated over a sink with air, GN₂, and vacuum under the hood. A special requirement of water flow at 20°C by the Bioresearch Breadboard could not be provided by the available GPL system but the requirement was met by the use of an ice bath system external to the GPL.

There was an excess of instrumentation lines available for this first test run. The only hardlined instrumentation is listed in Table 1. The remaining data were obtained from onboard readouts at the Crew Chief's station. More data should be hardlined to the test conductors console and the data handling room for future runs.

The push-to-talk intercom system proved to be a nuisance to the experimenter. An open-micorphone system would allow the experimenter to continue his work and still communicate outside the GPL. The intercom could still be used for onboard communication between experimenters and crew chief.

Several problems that developed resulted from test operations. The data collection capability of the video cameras was greatly hampered by their location. There was frequent camera blockage due to personnel inside the GPL during the test. The documentary photography added to these problems, and should be a duty of the crew chief in future tests.

A problem developed in providing proper working facilities to personnel visiting MSFC and involved in the test. They needed both office and storage space during their stay for the test.

All trash was collected at the end of each day. The trash collected during the entire test period was compacted to a volume of 1.16 cubic foot and weighed 9.91 pounds. No attempt was made to simulate a Sortie Lab concept for trash management.

Maintainability Assessment

An assessment of maintainability and supportability features of the GPL was made on a non-interference, informal basis, using an "Equipment Discrepancy Log." This log, plus observations during the test, and experimenters' comments during debriefings provided the basis for this assessment.

The maintainability characteristics of the GPL, with experiments installed, was considered excellent. All equipment was accessible for maintenance, and work space at the respective crew stations was sufficient so that limited operations could be continued even while maintenance was being performed on adjacent equipment. However, the consensus of the experimenters was that maintenance at crew station should be limited to module replacement, with module repairs performed at another location.

Competent maintenance service was available, on-call, for the support systems. The experimenters seemed well able to perform those maintenance tasks required on their equipment during the test period. Most agreed, however, that if more complex maintenance had been required (as it normally would during longer test periods), outside help would have been required. With a thorough indoctrination into experiment system equipment and adequate supply and technical documentation support, all the necessary maintenance services could have been performed by the Crew Chief.

CONCLUSIONS

This report has provided a narrative account of the experience gained by integrating Sortie Lab discipline experiments, with minimum constraints on the experimenter, into a general payload carrier, and conducting an 8 hour/day, 4½ day integrated test. A description of the GPL and the experiments has been provided. Observations on the adequacy of the GPL to support these experiments and over-all experiment operations have been discussed. As a result of these observations and the experience gained, the following conclusions are presented:

The assignment of experiment hardware integrators for experiments is very beneficial. Continuous use of the same personnel would provide a useful data bank for passing into Sortie Lab integration activity.

A handbook containing a description of GPL capabilities would be very supportive to testing and an aid in recruiting and integrating experiments.

Adequate engineering interface data, including maintenance requirements, are essential for experiment integration. The "PCS EXPERIMENTATION INFORMATION SHEET" would have provided these data if properly completed. Future testing may require more engineering support for hardware integrators.

The integration fixture used for Bioresearch Breadboard proved to be a valuable tool, and this concept should be considered for use in the Sortie Lab project.

The mission specialist (Crew Chief) proved to be indispensable for this test and appears as a requirement for Sortie Lab missions. His duties should be restricted to systems management, limited and clearly defined experiment support, documentary photography, and experimenter liason activities.

The use of a payload specialist (a P.I. for several experiments) is a practical concept for the payload carrier/experiment integration interface.

There should be a required experiment checkout in the laboratory prior to installation into the GPL.

GPL modifications are needed in the existing air-conditioning and plumbing systems. Re-evaluation and possibly relocation of existing standard laboratory equipment is needed.

Design changes would be required for several experiments in zero-g conditions; including such items as sinks, work benches, fluid handling and restraining mechanisms for equipment and crew.

There was an indication of a need for mechanical vibration isolation in areas of the Material Science discipline and complete isolation for rat metabolic monitoring phases of the Bioresearch Breadboard. This should be considered by Sortie Lab designers, with an assessment as to whether it should be supporting equipment, or a part of each experiment.

An area needs to be made available at MSFC for outside experimenters to use as office and storage space while participating in test runs.

Relocation of cameras and full use of pan-tilt-zoom cameras are desired for appropriate detailed Man/Systems data collection.

The z-floor arrangement provided adequate workstations and floor-space, so that five experimenters operating simultaneously did not cause a traffic problem.

APPROVAL

CVT/PCS PHASE I INTEGRATED TESTING


by

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Jackie D. Steadman

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.


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